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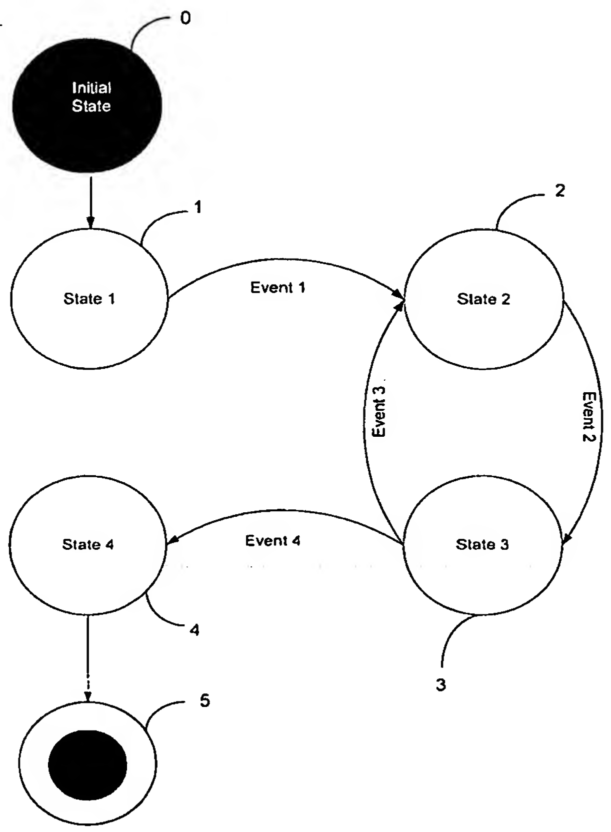
[Continued on next page]

(54) Title: A STATE MACHINE PROGRAMMING LAUGUAGE, A METHOD OF COMPUTER PROGRAMMING AND A DATA PROCESSING SYSTEM IMPLEMENTING THE SAME



(57) **Abstract:** A state machine language having a syntax requiring each state to be uniquely named and having associated state definition information including: (i) the definition of each action to be executed upon transition to that state; and (ii) the definition of each event which will cause transition to another state and the name of the next state to which operation will progress.

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A STATE MACHINE PROGRAMMING LANGUAGE, A METHOD OF COMPUTER PROGRAMMING AND A DATA PROCESSING SYSTEM IMPLEMENTING THE SAME

Field of the Invention

The present invention relates to a state machine programming language and its implementation. The state machine programming language of the invention enables direct programming in the state machine language to implement a state machine.

Background to the Invention

A state machine specifies the sequences of states that an object or an interaction goes through during its lifetime in response to events, together with its responses to those events. State machine models are particularly suited for modelling certain systems, such as automated voice-prompting telephone answering systems, traffic light systems, electronic circuits etc.

Currently available computer languages are generally purely procedurally based (eg. C/C++, Pascal, Java, Basic). To implement a state tree definition a programmer must create a state machine that executes the states. This can be time consuming utilising currently available computer languages and the solution may not be reusable.

Certain applications have been developed for creating state machines but they are generally limited to particular applications and/or complex and/or time consuming to implement.

US5485600 discloses a visual modelling system for defining relationships between objects. The relationships may be defined utilising a state table. A user is required to set up the environment for each state table, edit the state table for the particular application and then generate a program utilising information from the state table. The state table is utilised as a tool to generate a program utilising a pre-existing language. There is no suggestion that programming may be effected directly via a state machine programming language. The programming method disclosed in this patent is time consuming and laborious to implement and does not facilitate the reuse of programming code.

Summary of the Invention

It is an object of the present invention to provide a state machine programming language that allows a programmer to program directly according to a state machine model that clearly defines the structure of a state machine or to at least provide the public with a useful choice.

According to a first aspect of the invention there is provided a method of computer programming utilising a state machine programming language including the steps of:

defining a plurality of states according to the syntax of the state machine programming language, each state having state definition information including:

i. a definition of each action to be executed upon transition to that state; and

ii. a definition of each event which will cause transition to another state and the name of the next state to which operation will progress.

According to a further aspect there is provided a data processing system including:
a storage device containing state information according to the syntax of a state machine programming language including:
definitions for a plurality of states in which each state definition includes:

i. a definition of each action to be executed upon transition to that state; and
ii. a definition of each event which will cause transition to another state and the next state to which operation will progress; and

a processor which executes the actions in accordance with the state information for the current state and effects state transitions in response to event information.

According to a further aspect there is provided a computer programmed to operate according to a state based programming language wherein to create a program the computer requires a user to enter state information according to a required syntax for each state including:

i. a state name;
ii. actions to be executed upon transition to the state; and
iii. each event which will cause transition to another state and the name of the next state.

Brief Description of the Drawings

The invention will now be described by way of example with reference to the accompanying drawings in which:

Figure 1: shows a simple state machine.

Figure 2: shows a computer system suitable for executing the state machine programming language of the invention.

Figure 3: shows a state machine for implementing an automated voice-prompting telephone answering system.

Detailed Description of the Best Mode for Carrying Out the Invention

Referring to Figure 1 a graphical representation of a state machine is shown. From an initial State 0 operation may progress to a first State 1. Whilst in State 1 certain actions may be executed. Upon the occurrence of an Event 1 operation may progress to State 2 where another set of actions may be performed. Upon the occurrence of Event 2 operation may proceed to State 3 where a further set of actions may be executed. Upon the occurrence of Event 3 operation may return to State 2 or, upon occurrence of Event 4 operation may proceed to State 4 where a further set of actions may be executed. Operation may then terminate at a final State 5.

Although state models have been used to model sequential processes, state diagrams and tables have merely been utilised as a tool to develop a resulting program.

According to the present invention a state machine language has been developed whereby a programmer may structure a program in the state machine language in a manner reflecting the logical operation within a state machine diagram.

According to the invention a machine based programming language is provided which separates state definitions from procedural code and treats the procedural code as an adjunct to the main state handling code. This allows a programmer to clearly define the structure of a state machine and simplifies the writing and maintaining of programs to implement state machines.

According to the state machine language of the invention each state is given an unique state name by the programmer; the actions to be executed whilst the program is in that state are defined; and the events causing the program to progress to a new state along with the new state are also defined. The format for defining each state is as below:

```
State Name
        actions
                Function call 1
                Function call 2
                Function call n
        events
                event 1: next state 1
                event 2: next state 2
                event n: next state n
end
```

One or more action may be defined for each state. A number of states may execute the same action. One or more event may trigger a transition to a new state. Different events may trigger transitions to different states.

Each state is preferably defined within a block of code. Each state definition is preferably separated from each other state definition by a blank line.

The actions defined within each state definition may be common functions which may be defined within a "functions" definition. This may be conveniently provided at the end of the state definitions.

The events that may trigger a state transition may be inputs from input devices, the outputs of function calls etc. Any function may execute any other function which will, when executed, return to the calling parent function. A function is represented by its name, its interface and a set of instructions defining the functions operation as follows:

Function name
Interface
Instructions defining the function's operation

Within a state machine it may be desirable to identify a portion of the state tree as a sub-branch. When operation proceeds to the sub-branch, operation may proceed according to the sub-branch state definition until operation proceeds to the final state of the sub-branch, whereupon operation then returns to the parent state tree definition. This approach may be applied to any sub-branch depth. Accordingly, for example, the state diagram shown in figure 1 may represent a sub branch of a larger state diagram. The section of definitions for states 1-4 may be identified as a sub-branch. Such a sub-branch may be called as an action for a state of the parent state tree definition. This may enable commonly used sub-branches to be defined once and to be used by any parent state. This allows state definitions to be compact, simple, easy to understand and better structured. This approach is analogous to a parent function calling another child function that returns back to the calling parent when it is finished.

Referring now to figures 2 and 3 a computer for implementing the state machine language of the invention is described in conjunction with an automated voice prompting telephone answering system application by way of example only.

Referring to figure 2 the computer may be of standard architecture including a microprocessor 6 which receives input from an input device 7 such as a keyboard. RAM 8 provides temporary data storage and hard disk drive 9 provides permanent storage. An operating system and the state machine language program may be stored on hard disk 9 and loaded into RAM during operation. Processor 6 outputs graphics information to graphics driver 10 which drives display 11. Typically a user will type in a code which will be displayed by display 11, stored on hard disk drive 9 and executed by processor 6.

Figure 3 illustrates a state machine diagram for a telephone voice prompting system for accessing departments of a business. From Initial State 20 operation proceeds to state 21 where a caller is asked whether operator assistance is required. If "0" is pressed operation proceeds to State 22 and the call is connected to an operator. If a "1" is pushed operation proceeds to State 23. If "1" is selected the call is connected to gardening in State 24. If key "2" is selected operation proceeds to step 25 and the call is connected to the service desk. Once the required functions are executed in states 22, 24 and 25 operation proceeds to final state 26. If any invalid key is selected in State 23 operation proceeds to step 27 and returns to State 23.

The following is a possible implementation of such a system utilising the state machine language of the invention:

```
// The first state is always the start state for the machine

State AskIfOperatorRequired
                actions
                        SendPrompt (''Press 0 to contact an operator or 1
                        for a list of departments'');
                event
                ''0''   :       ConnectCallToOperator;
                ''1''   :       SelectDepartment;
end

State ConnectCallToOperator
                actions
                        SendMessage (''Connecting to the operator'');
```

```
                    ConnectCall ( Operator );
            event
                    default:        FINAL_STATE;
end

State SelectDepartment
            actions
                    SendPrompt ("Please select the number of the
            department you are interested in or * to talk to the
            operator");
            event
                    '1' :  ConnectCallToGardening;
                    '2':   ConnectCallToServiceDesk;
                    '*':   ConnectCallToOperator;
                    default:  InvalidDepartment;
end

State   ConnectCallToGardening
            actions
                    SendMessage ("Connecting to the Gardening
department");
                    ConnectCall ( Gardening);
            event
                    default:  FINAL_STATE;
end

State ConnectCallToServiceDesk
            actions
                    SendMessage ("Connecting to the Service
Desk");
                    ConnectCall (ServiceDesk);
            event
                    default: FINAL_STATE;
end

State InvalidDepartment
            actions
```

```
                        SendMessage (''Sorry, no such department
number'');
                        Desk'');
                event
                        default:  SelectDepartment;
end


FUNCTIONS

        function ConnectCall (department)
        {
                ExtensionNumber = lookup (department);
                RouteVoiceCall (ExtensionNumber);
        }

        function SendPrompt (prompt)
        {
                VoiceCotent = ConvertToVoice (prompt);
                SendVoice (VoiceContent);
                Key = GetUserResponse();
                Return key;
        }

        function SendMessage (message)
        {
                VoiceContent = ConvertToVoice (message);
                SendVoice (Voice Content);
        }
```

In this example the first state "AskIfOperatorRequired" is the initial state. The action definition for this state includes the "SendPrompt" function. This function is defined at the end of the programme definition which instructs the content to be converted to voice. The bracketed content "press "0" to contact an operator or "1" for a list of departments" will thus be sent as a voice message to the caller. In the event definition the event of pressing key "0" results in a transition to state ConnectCallToOperator and pressing "1" results in a transition to the state SelectDepartment. The other state definitions are likewise defined by their names, actions and the events (each event having an associated next state).

The functions are defined by their name (eg. "ConnectCall"), interface (eg. Department) and instructions (eg. ExtensionNumber = lookup (department); RouteVoiceCall (ExtensionNumber).

By way of comparison the following code is an example of an implementation of the state machine diagram of figure 3 written in a procedural programming language.

```
program VoicePrompter ( )
begin
        currentState = AskIfOperatorRequired
        While currentState != FINAL_STATE do
        begin
                key = GetUserKey( )
                select CurrentState of
                        case AskIfOperatorRequired :
                        {
                                key = SendPrompt (``Press 0
        to contact  an operator or 1 for a list of departments''):
                        if key = `0' then
                                CurrentState =
        ConnectCallToOperator;
                        Else
                                CurrentState =
        SelectDepartment;
                        }
                        case ConnectCallToOperator:
                        {
                                SendMessage (``Connecting to the
operator'');
```

```
                    CurrentState = FINAL_STATE;
                    ConnectCall ( Operator )
          }
          case SelectDepartment:
          }
                    Key = Sendprompt ( ``Please select the
number of the department you are interested in or * to talk to
the operator'');
                    If key = '1' then
                    CurrentState =
ConnectCallToGardening;
          Else
          If key = '2' then
                    CurrentState =
ConnectCallToServiceDesk;
          Else
          If key = '*' then
                    CurrentState =
ConnectCallToOperator;
          Else
                    CurrentState =
Invalid Department;
          }
          case ConnectCallToGardening:
          {
                    SendMessage (''Connecting to the
Gardening department'');
                    CurrentState = FINAL_STATE;
                    ConnectCall ( Gardening );
          }
          case ConnectCallToServiceDesk:
          }
                    SendMessage (''Connecting to the Service
Desk'');
                    CurrentState = FINAL_STATE;
                    ConnectCall (ServiceDesk);
          }
```

```
                    case InvalidDepartment:
                    {
                            SendMessage ("Sorry, no such
        department number");
                            CurrentState =
            SelectDepartment;
                    }
                end case
          end while
            end program


            function ConnectCall (department)
            {
                    ExtensionNumber = lookup (department);
                    RouteVoiceCall (ExtentionNumber);
            }


            function SendPrompt (prompt)
            {
                    VoiceContent = ConvertToVoice (prompt);
                    SendVoice (VoiceContent);
                    Key = GetUserResponser ();
                    Return (key);
            }


            function SendMessage (message)
            {
                    VoiceConent = ConvertToVoice (message);
                    SendVoice (VoiceContent);
            }
```

It will be noted that the state information is buried amongst procedural control statements and the states, actions and transitions of the state machines are difficult to discern.

It will thus be seen that the invention provides a state machine language which allows a programmer to clearly define the structure of a state machine, and thus facilitate the writing and maintaining of programs implementing state machines. The syntax of the state machine language of the invention allows states and transitions to be explicitly defined, making the state machine structure readily discernible. This greatly simplifies writing and maintaining programs written in the state machine language of the invention.

CLAIMS:

1. A method of computer programming utilising a state machine programming language including the steps of:

defining a plurality of states according to the syntax of the state machine programming language, each state having state definition information including:

i) a definition of each action to be executed upon transition to that state; and

ii) a definition of each event which will cause transition to another state and the name of the next state to which operation will progress.

2. A method as claimed in claim 1 wherein each state name, its associated actions and events are grouped together.

3. A method as claimed in claim 1 or claim 2 wherein functions called by actions are defined separately from the state definitions.

4. A method as claimed in claim 3 wherein the functions are defined following the state definitions.

5. A method as claimed in any proceeding claim wherein multiple actions are executed upon transition to a state.

6. A method as claimed in any proceeding claim wherein an action is executed by a plurality of states.

7. A method as claimed in any one of the proceeding claims wherein at least two events are defined for a state, each causing a transition to a different state.

8. A method as claimed in any one of the proceeding claims wherein a state transition is contingent upon multiple events.

9. A method as claimed in any one of proceeding claims wherein one or more state includes one or more sub states.

10. A method as claimed in claim 9 wherein the sub states are defined in the manner defined in any one claims 1 to 8.

11. A method as claimed in any one of the proceeding claims wherein an event is a default event, being any or no action.

12. A method as claimed in one of the preceding claims wherein the state definitions are entered via a user input device of a computer.

13. A method as claimed in one of the preceding claims wherein the state definitions are stored in computer readable media.

14. A computer program produced according to the method of any one of the preceding claims.

15. A computer readable medium embodying a computer program as claimed in claim 14.

16. A computer programmed to operate according to the computer program of claim 14 or claim 15.

17. A data processing system including:
a storage device containing state information according to the syntax of a state machine programming language including:
definitions for a plurality of states in which each state definition includes:
    i) a definition of each action to be executed upon transition to that state; and
    ii) a definition of each event which will cause transition to another state and the next state to which operation will progress; and
    iii) a processor which executes the actions in accordance with the state information for the current state and effects state transitions in response to event information.

18. A system as claimed and 17 wherein the storage device contains state information in accordance with any one of claims 1 to 13 at.

19. A system as claimed in claimed 17 or claim 18 wherein the event information is input data.

20. A system as claimed in claimed 17 or claim 18 wherein the event information is the output of one or more actions.

21. A system as claimed in any one of claims 17 to 20 wherein the system is an automated voice-prompting telephone answering system.

22. A computer programmed to operate according to a state based programming language wherein to create a program the computer requires a user to enter state information according to a required syntax for each state including:

i) a state name;

ii) actions to be executed upon transition to the state; and

iii) each event which will cause transition to another state and the name of the next state.

23. A computer as claimed in claim 22 including a display device which displays state information for each state within a display sub region.

24. A computer as claimed in claim 23 wherein the state information for each state is displayed as a separate block of text.

25. A computer as claimed in claim 23 or 24 wherein functions called by actions are displayed in a separate function block.

26. A computer as claimed in any one of claims 22 to 25 which executes the defined actions for a state upon transition to that state and effects transition to a next state upon the occurrence of a specified event.

27. A computer as claimed in claim 26 wherein the computer executes the actions by calling functions from the function block.

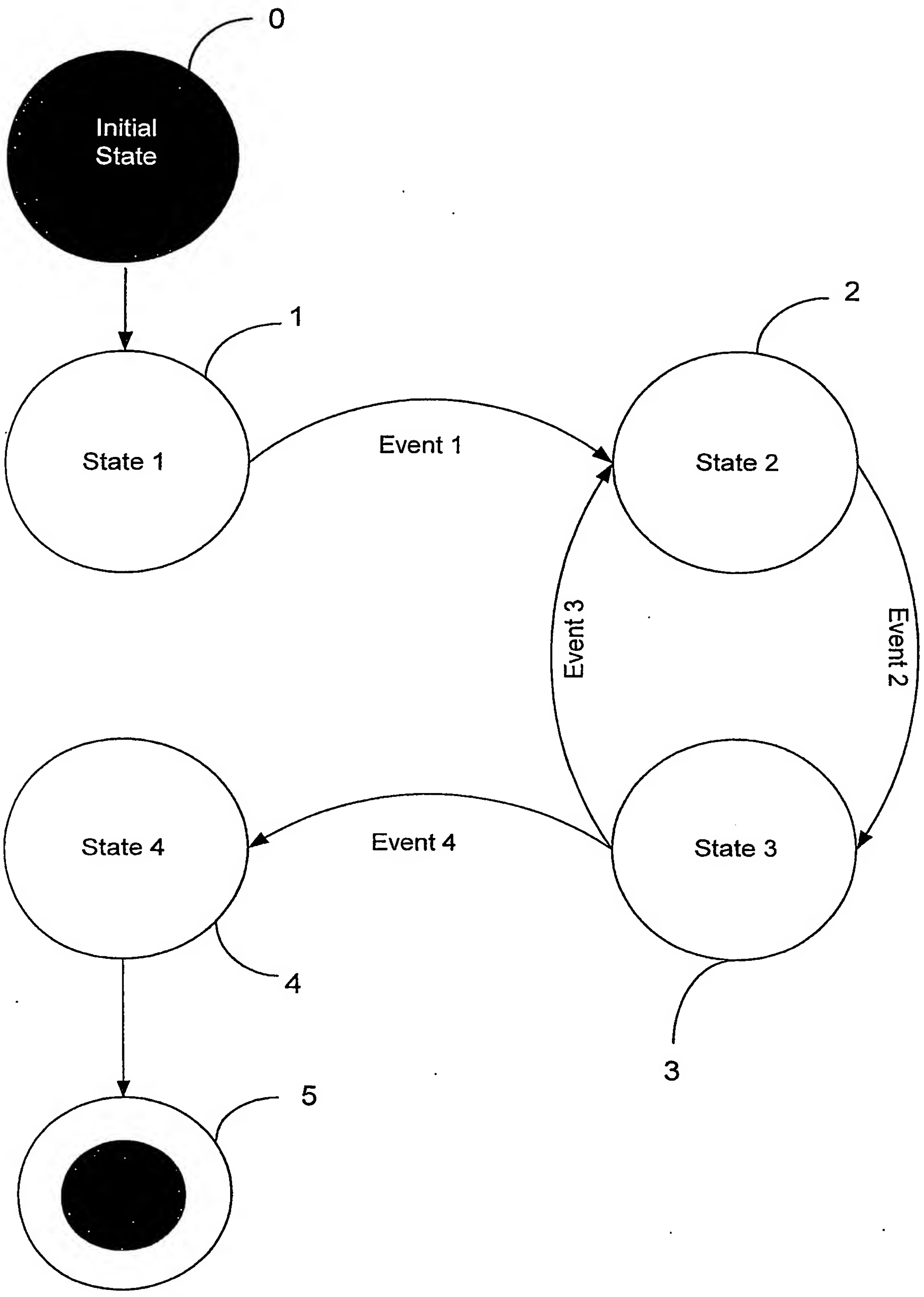
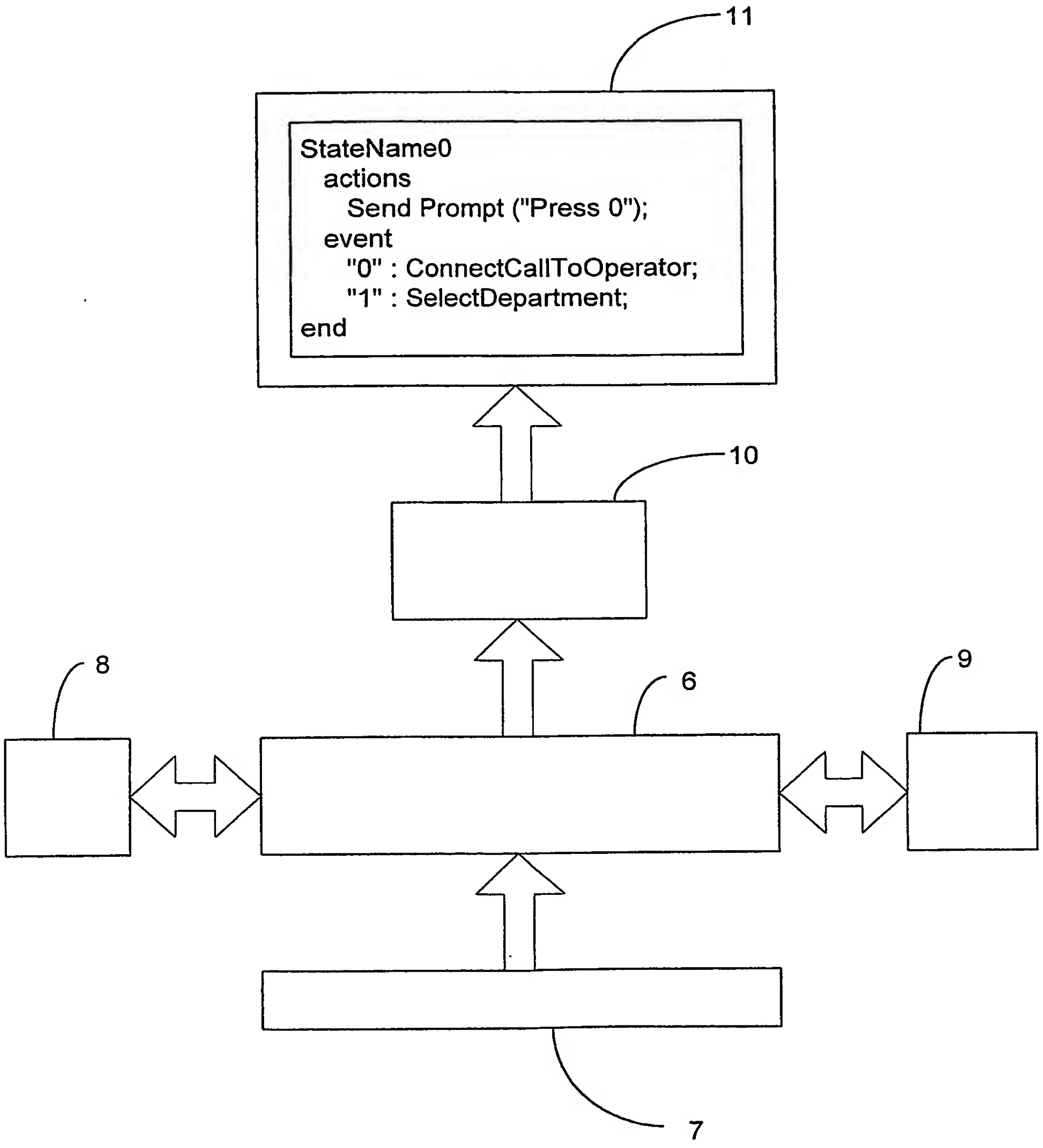

0
Initial State
1
State 1
Event 1
2
State 2
Event 3
Event 2
State 4
Event 4
State 3
4
3
5

Figure 1



```
StateName0
  actions
    Send Prompt ("Press 0");
  event
    "0" : ConnectCallToOperator;
    "1" : SelectDepartment;
end
```

Figure 2

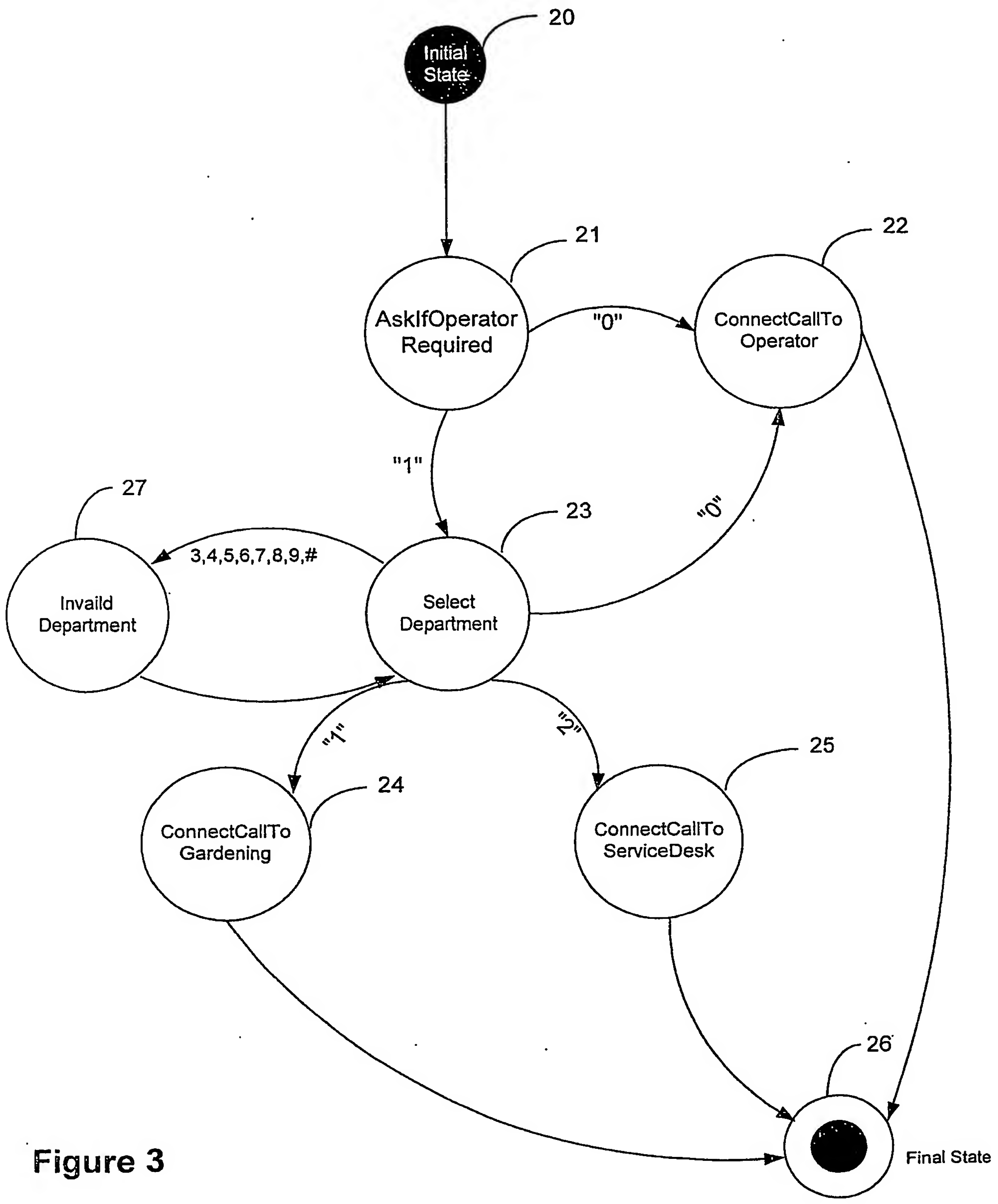

20
Initial State
21
AskIfOperator Required
22
ConnectCallTo Operator
"0"
"1"
27
23
"0"
3,4,5,6,7,8,9,#
Invaild Department
Select Department
"1"
"2"
25
24
ConnectCallTo Gardening
ConnectCallTo ServiceDesk
26
Final State

Figure 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/NZ01/00232

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl. 7: G06F 9/44

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
WPAT,IEEE (state machine language)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	US 5 542 070 (LeBlanc et al.) 30 July 1996 Abstract, column 3 line 52 to column 5 line 20, claim 2	1,13-16 17-20,22,27
Y	WO 00/78022 (Telstra R&D Management Pty. Ltd.) 21 December 2000 Abstract	21
Y	US 5 920 718 (Uczekaj et al.) 6 July 1999 Abstract, figures, claims	17-20,22,27

[X] Further documents are listed in the continuation of Box C [X] See patent family annex

*	Special categories of cited documents:
"A"	document defining the general state of the art which is not considered to be of particular relevance
"E"	earlier application or patent but published on or after the international filing date
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O"	document referring to an oral disclosure, use, exhibition or other means
"P"	document published prior to the international filing date but later than the priority date claimed
"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&"	document member of the same patent family

Date of the actual completion of the international search 14 December 2001	Date of mailing of the international search report 20 DEC 2001
Name and mailing address of the ISA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA E-mail address: pct@ipaustralia.gov.au Facsimile No. (02) 6285 3929	Authorized officer **DALE E. SIVER** Telephone No : (02) 6283 2196

International application No.
PCT/NZ01/00232

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	"A Tool for Practical Reasoning about State Machine Designs" (Cant et al.) Proceedings of the 1996 Australian Software Engineering Conference ASWEC -'96 Whole document, esp. Sections 1.1 and 2	1,17,22
A	US 5 937 181 (Godefroid et al.) 10 August 1999 Abstract, Summary	1

INTERNATIONAL SEARCH REPORT Information on patent family members	International application No. **PCT/NZ01/00232**

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report		Patent Family Member	
US	5542070	CA	2122182
WO	2000/78022	AU	2000/50545
US	5920718	NO	MEMBERS
US	5937181	NO	MEMBERS

END OF ANNEX